Processing All-Optical Data using Optical Nonlinearities and Nanophotonic Materials and Devices

Y. Fainman
Department of Electrical and Computer Engineering
University of California at San Diego
La Jolla, California 92093-0407
Tel: (858) 534-8909; Fax: (858) 534-1225; E-mail: fainman@ece.ucsd.edu

Ultrafast and Nanoscale Optics Group, http://topaz.ucsd.edu

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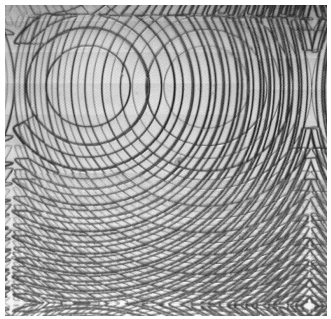
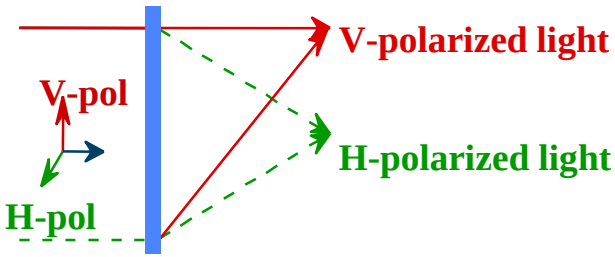
Optical Multistage Interconnection Network

Polarization selective Fresnel lenses combine 1×2 switching with 3D interconnectivity

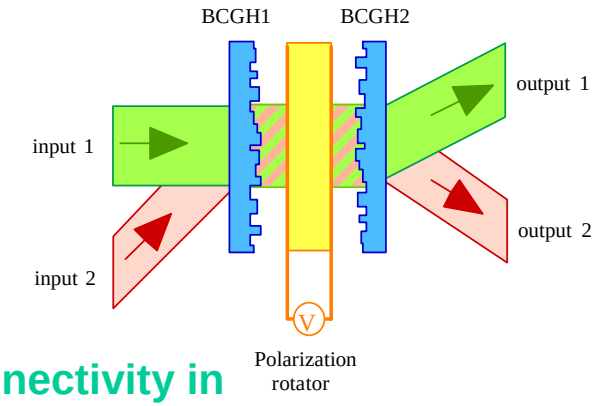
BCGH with superimposed Fresnel lens encoding



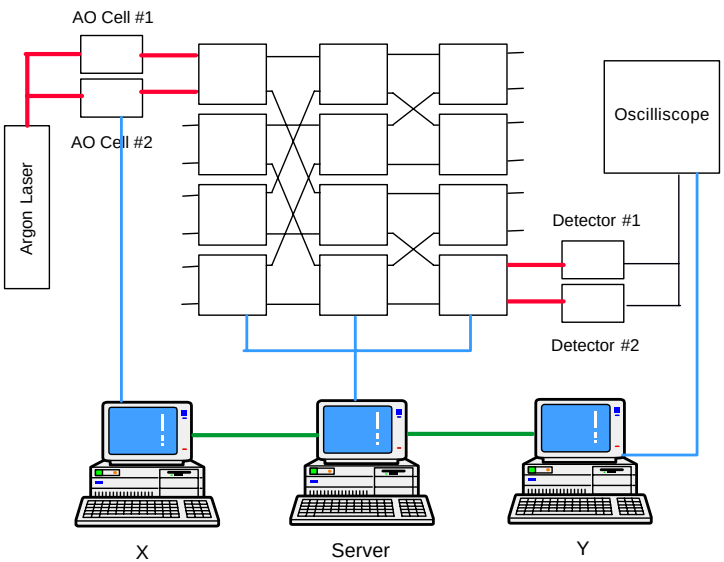
BCGH has independent response to orthogonal polarizations

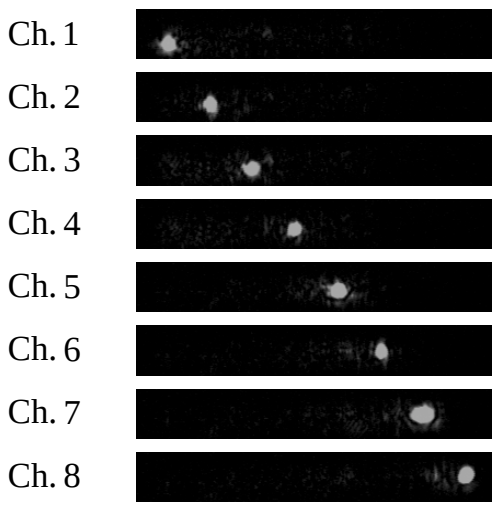


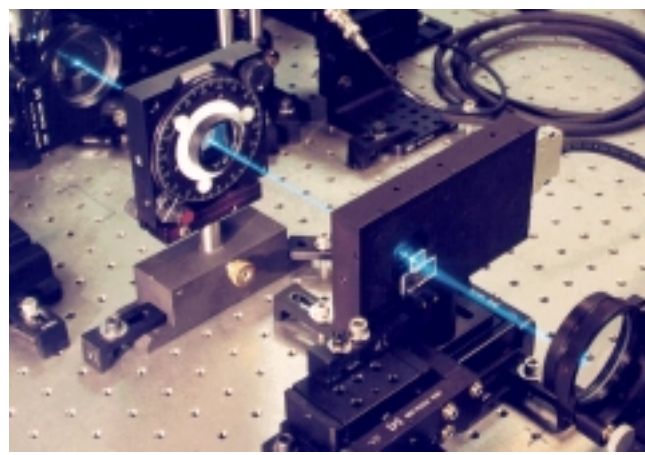
Dilated Bypass Exchange 2×2 Switch requires only 2 BCGH and 1 PR element



2×8 folded MIN demonstration shows complete interconnectivity in compact cavity design: 1×8 output exhibits high contrast and uniformity





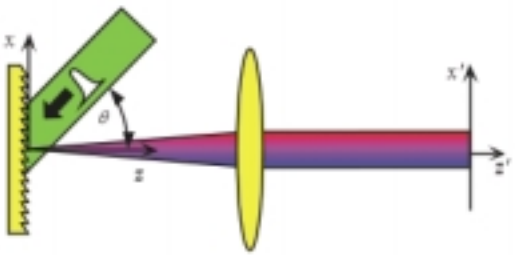


Krishnamorthy, F. Xu, J. Ford, Y. Fainman, " Polarization-controlled multistage switch based on birefringent computer generated holograms," *Appl. Opt.*, **36**, 997-1010, 1997
D. M. Marom, P.E. Shames, F. Xu, and Y. Fainman, "Folded free-space polarization-controlled multistage interconnection network", *Appl. Opt.*, 37, 6884-6891, 1998

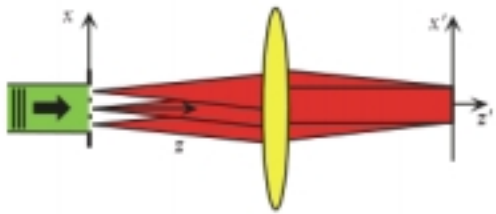
Generalized Femtosecond-rate Processing with Optical Nonlinearities

Different optical signal processing alternatives are available by wave mixing different information carrying waves.

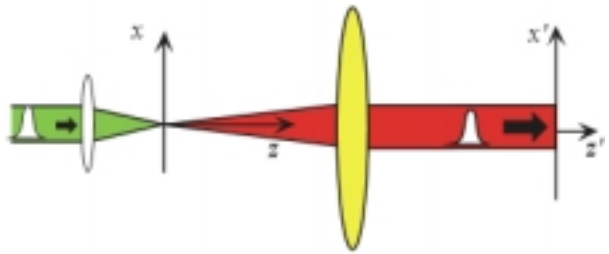
Spectrally decomposed wave



Spatial information wave



Ultrashort pulse signal

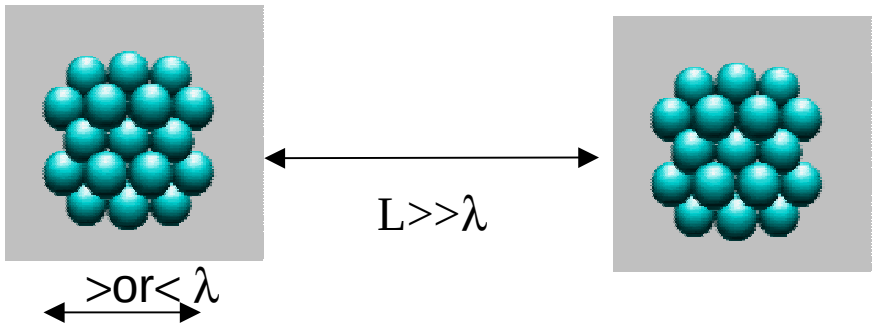


Input 1	Input 2	Input 3	Output
SDW	Spatial information wave	Spatial reference - plane wave	Ultrashort pulse signal: space-to-time conversion
SDW	Spatial information wave	Spatial information wave	Ultrashort pulse signal: correlation of the spatial channels
SDW	SDW	X	Spatial information wave: time-to-space conversion
SDW	SDW	SDW of the complex amplitude signal	Ultrashort pulse signal: phase conjugation

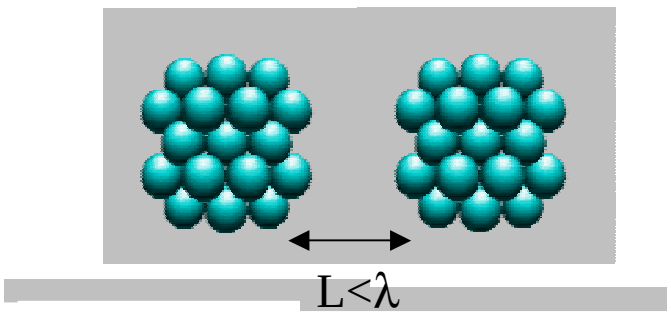
D.Marom, D.Panasenko,P.-C.Sun;Y. Mazurenko,Y. Fainman, IEEE Journal of Selected Topics in Quantum Electronics, 7, 683 (2001)

Nanophotonics: Far, Near and Local Field Optical Systems

Inhomogeneous systems with variable scale *Polarizability* of atomic-scale homogeneous sub-systems:

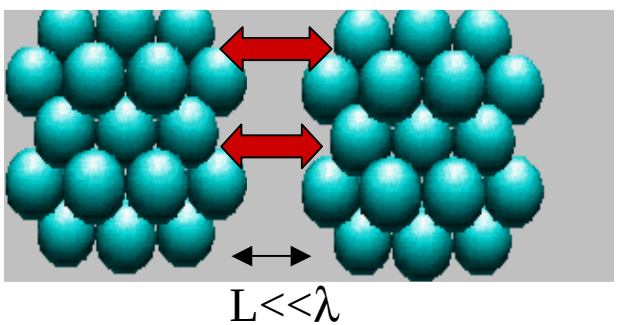


Far atomic-scale sub-systems (e-m decoupled such as macro- and micro-optics)



Near atomic-scale sub-systems (e-m coupled such as artificial dielectrics, composites, and resonant PBGs)

Intrinsic interactions

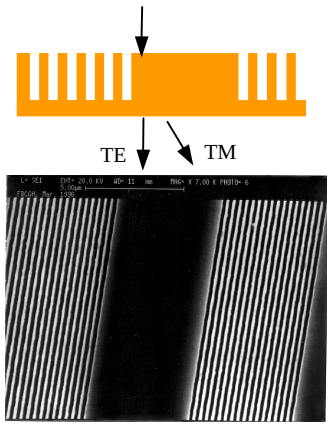


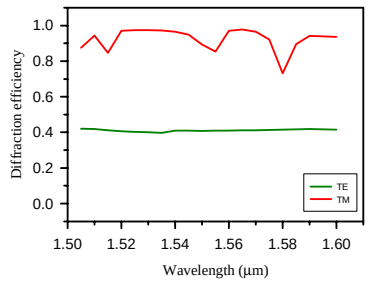
Local atomic-scale sub-systems (material internal interactions in absence of e-m field such as superlattice, quantum wires, dots, etc)

Inhomogeneous Optical Nanostructures: Materials and Devices

Form Birefringent Computer Generated Hologram :

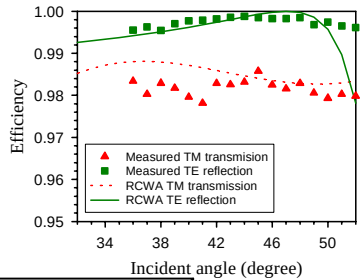
Multi-functionality and arbitrary phase profile

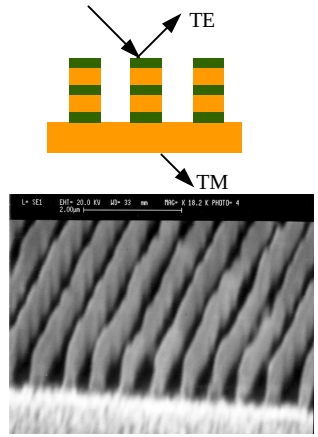




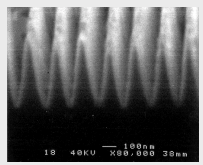
Anisotropic Spectral Reflectivity Polarization Optics :

Large spectral and angular bandwidth, compact size, and normal incident operation



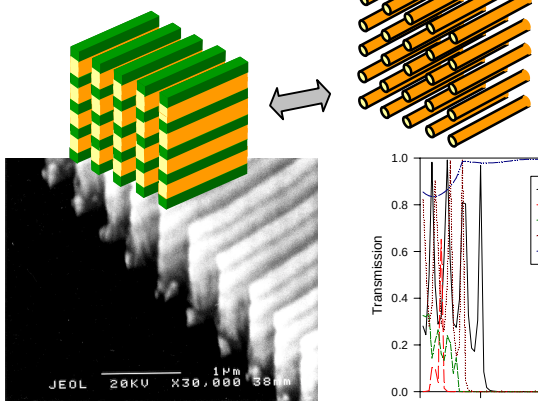


Near-field interactions modify bulk material properties

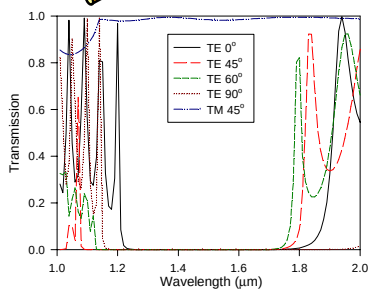


Experimental example* :
Material : GaAs
Incident wavelength = 920 nm
Grating period = 200 nm
Grating depth = 490 nm
Phase difference $\Delta\phi = 162.5^{o}$
$\Rightarrow \Delta n/n = 0.47$

Near-field Optical Materials :

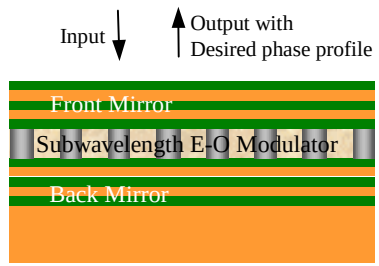


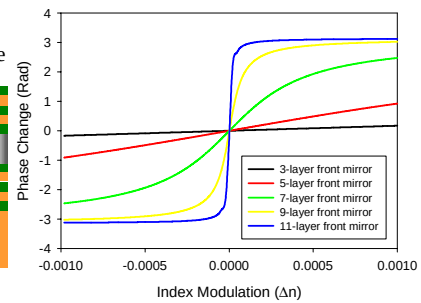
3-material photonic crystal



Near Field Programmable Diffractive Optical Element :

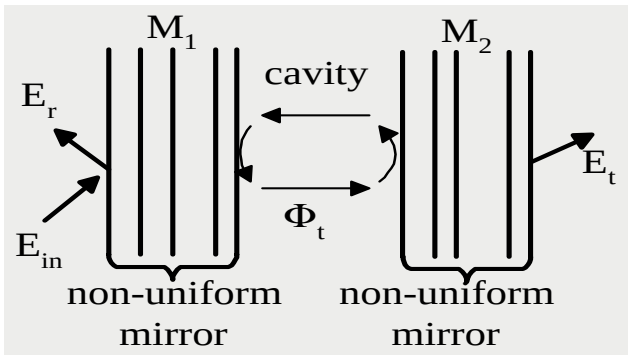
Low voltage, compact size and programmability





Approaches to Optical Delay

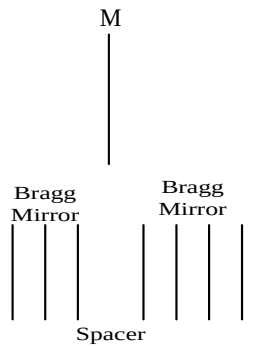
Atomic Resonance, Free Space Delay, Structural Resonance



$$v_g = \left(\left. \frac{dk}{d\omega} \right|_{\omega_0} \right)^{-1} = \frac{c}{n(\omega_0) + \omega_0 \left. \frac{dn(\omega)}{d\omega} \right|_{\omega_0}}$$

Normal dispersion ($dn/d\omega>0$): "Slow" light ($v_g << c$)

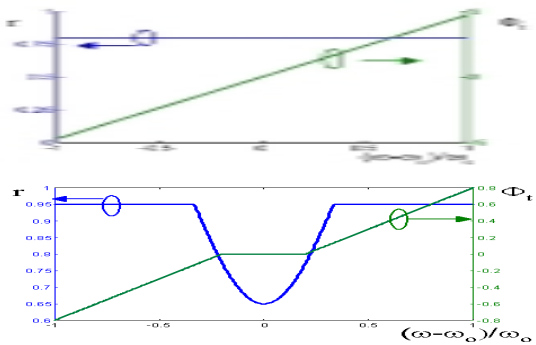
Anomalous dispersion ($dn/dw<0$): "Fast" light ($v_g > c$)

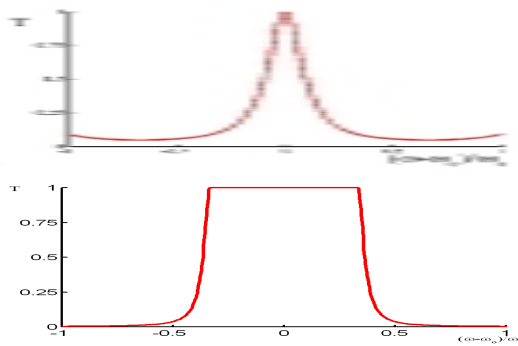


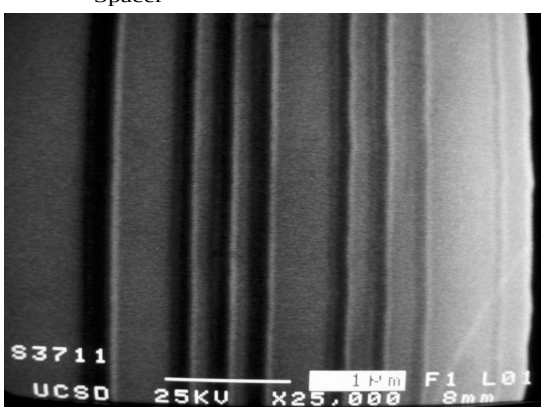
$\Phi_t \propto \omega$

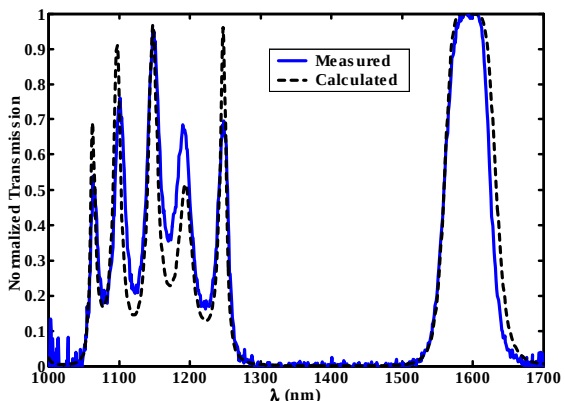
$\Phi_{t@p}=2n\pi$

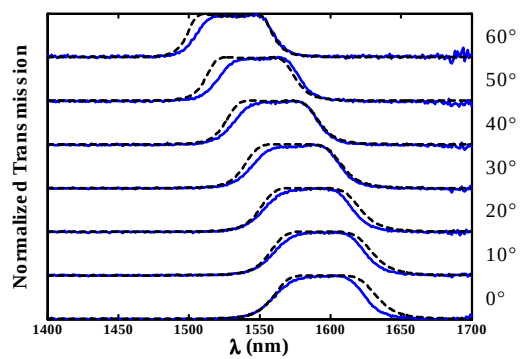
$\Phi_{t@s} \propto \omega$





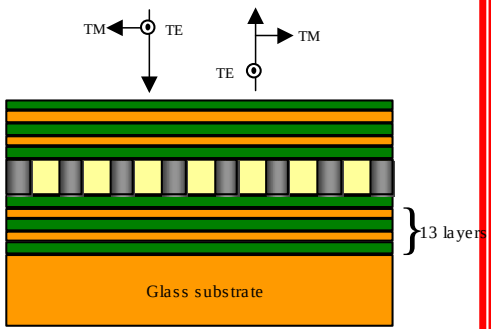


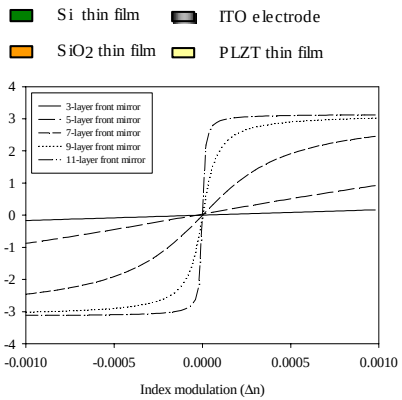


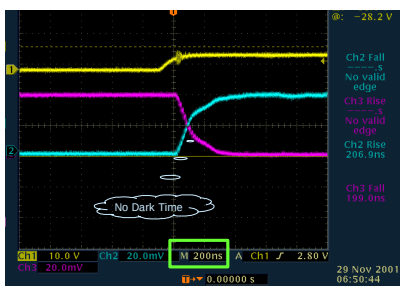


Nanostructures for Fast Switching and Control

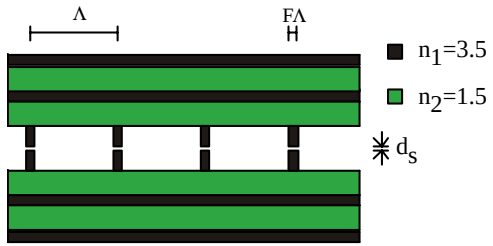
Resonantly enhanced EO control

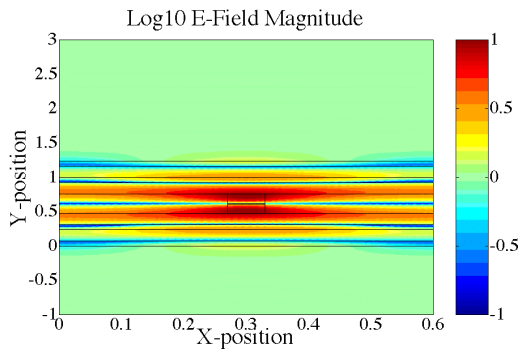


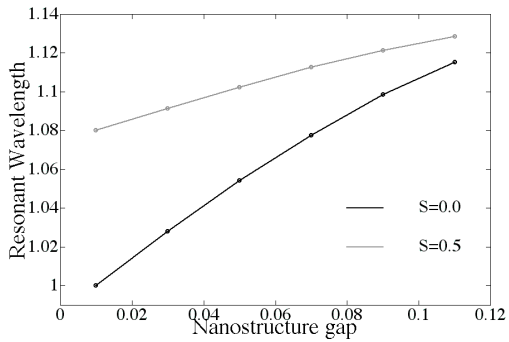




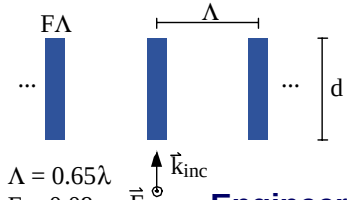
Near-field enhanced EO/nanoMEMS control

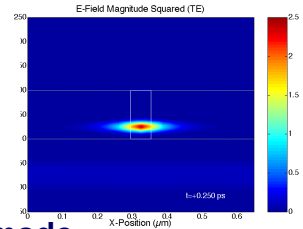




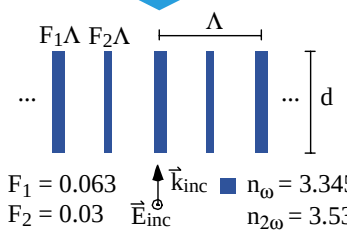


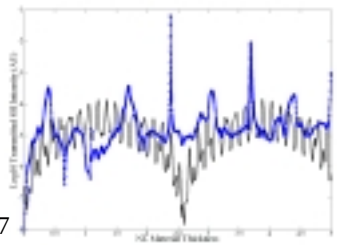
Field localization for efficient nonlinear interactions and control

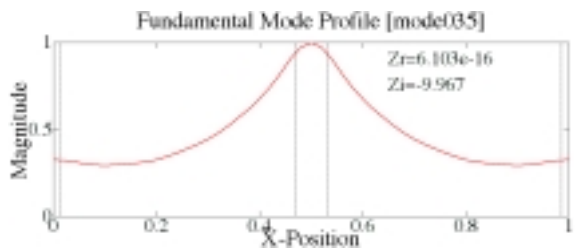


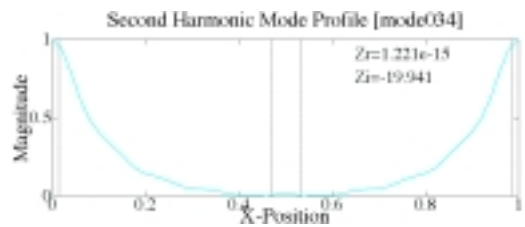


Engineer mode phase velocities



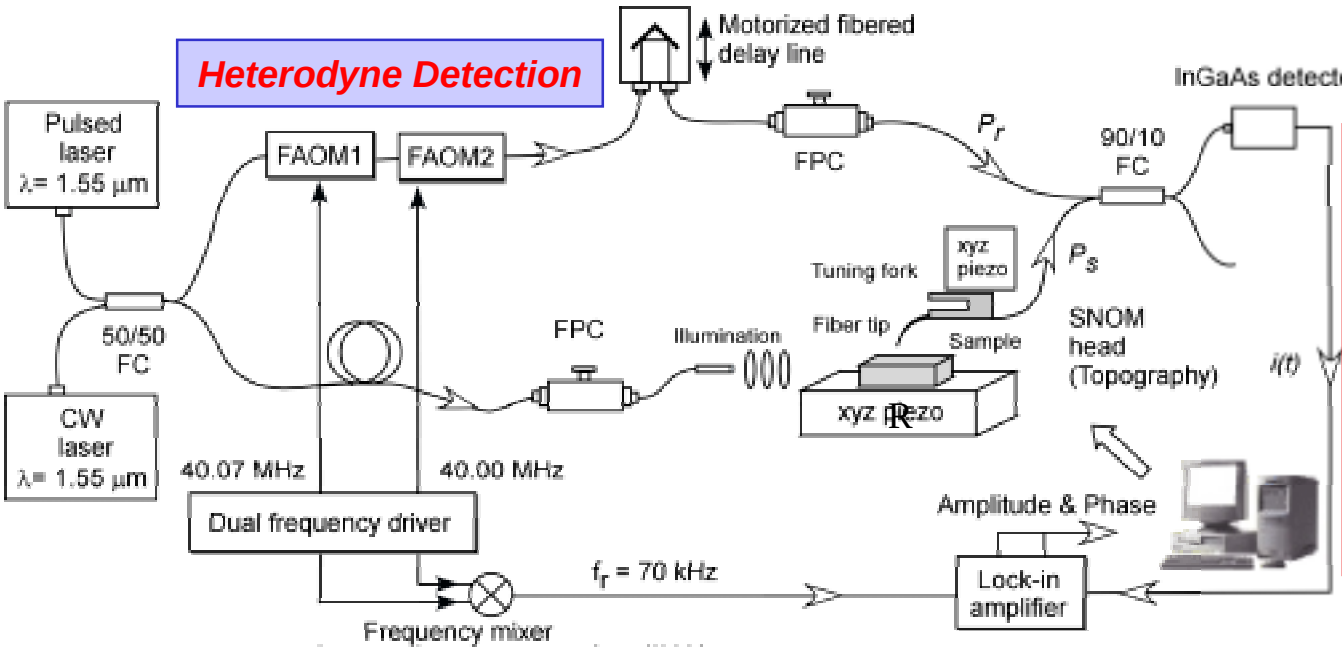






Nanoscale Characterization of Near-field Complex Amplitude with Femtosecond Resolution

Objective: Characterization and testing nanophotonic devices and systems, and understanding near field interactions between light and quantum systems



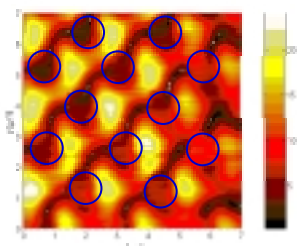
Advantages:

- **Shot-noise limited (maximal SNR)**
- **Low power signal detection**
- **High phase resolution**

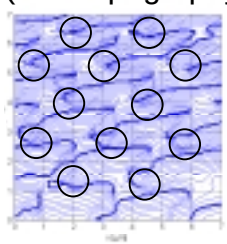
$$I = I_o + I_r + 2\sqrt{I_o I_r}\cos\left[2\pi\Delta f t + \varphi\right]$$

SEM picture
Λ = 1.5 μm

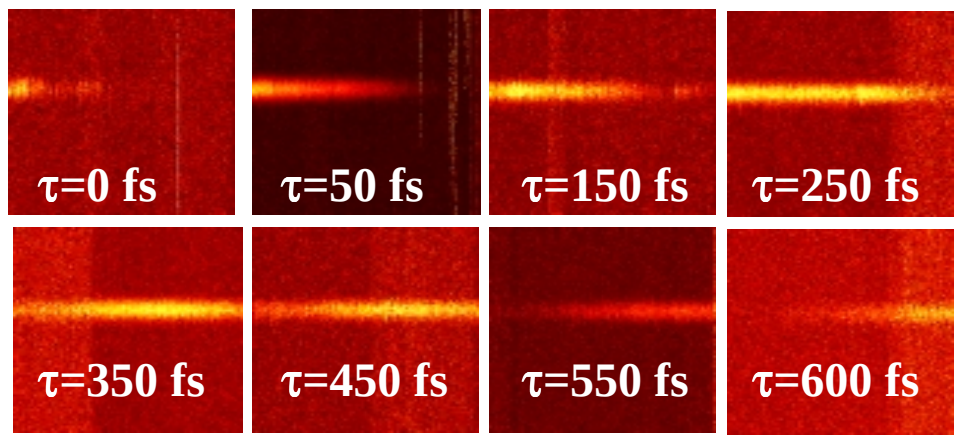
Amplitude
(with topography)



Phase
(with topography)



Propagation of an ultrashort pulse in a waveguide



Technologies enabling processing data in the optical domain.

- Optical address/header processing/recognition
- Optical buffer
- Switching fabric
- 3-R (retiming, reshaping, regeneration)
- Re-routing
- Wavelength conversion
- Contention detection/resolution